TITLE OF THE INVENTION
Bumper Core

BACKGROUND OF THE INVENTION

5   This invention relates to a core body of a bumper for attachment to a front of a vehicle such as an automobile.

A front bumper of an automobile generally serves to relax a shock to a driver or passenger and to prevent
10   damages of the automobile body at a time of collision of the automobile with an object. A foamed polypropylene-based resin molding has been used as such a bumper core because of its excellent shock absorbing property and lightness in weight (JP-A-S58-221745 and JP-A-H11-334501).
15   The conventional front bumpers have been so constructed as to protect an automobile body when the automobile traveling at a speed of 4 or 8 km/hour collides with an object. With such a construction, however, pedestrians are likely to be seriously injured by
20   collision with the bumper of an automobile. In particular, the bumper strikes the knee area of an adult pedestrian, which results in complex, unrecoverable fracture with permanent damage.

Thus, there is an increasing demand for a vehicle
25   front bumper core which can protect a pedestrian on the occasion of collision with an automobile. More specifically, there is a need for a bumper core which can absorb energy of collision between the pedestrian and the automobile traveling at a relatively high speed of, for
30   example, 40 km/hour, so that the leg impact can be reduced and serious knee injury can be avoided.

Even with the conventional bumper core constructions, it is possible to reduce the collision impact and to increase energy absorption by using a core material having
35   a low compression modulus and a large volume. However,

since the recent cars are designed to pursue energy saving and an increase of the inside occupation space, the bumper is required to be compact and to have a light weight. At present, no bumper cores on the market satisfy the above

5   requirements at the same time.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a bumper core for vehicles with which pedestrian

10   protection is considerably improved.

Another object of the present invention is to provide a compact, light weight bumper core which can absorb collision energy in a satisfactory degree.

It is a special object of the present invention to

15   provide a bumper core which can absorb shock of collision between a pedestrian and an automobile traveling at a relatively high speed of, for example, 40 km/hour and which can reduce leg impact on the pedestrian.

In accomplishing the foregoing objects, there is

20   provided in accordance with one aspect of the present invention an elongated bumper core of a polyolefin-based resin-containing foam having a density of 0.045-0.2 g/cm^3 and showing a compressive load of F_{20} at 20 % strain, a compressive load of F_{40} at 40 % strain and a compressive

25   load of F_{60} at 60 % strain when compressed by a rigid pipe having an outer diameter of 70 mm at a compression speed of 500 mm/minute, wherein the ratio F_{20}/F_{40} is in the range of 0.6-1.3 and the ratio F_{60}/F_{40} is in the range of 0.75-1.3.

30   In another aspect, the present invention provides an elongated bumper core of a polyolefin-based resin-containing foam having a density of 0.045-0.2 g/cm^3, comprising a front section extending lengthwise of said bumper core, and at least two, longitudinally extending,

35   vertically spaced apart protrusions each extending

rearwardly from said front section, wherein each of said
protrusions has a thickness in the vertical direction of T
mm and a length in the front to rear direction of H mm,
wherein the ratio of H/T is 2 to 10, wherein the
5   polyolefin-based resin-containing foam from which said
protrusions are formed has a bending load of 35-400 N,
said bumper core having a true volume VT cm^3 and including
one or more weight reducing portions having a total volume
of VV cm^3, wherein VT and VV satisfy the following
10 condition:

$$0.2 \leq VT/(VT + VV) \leq 0.7.$$

In a further aspect, the present invention provides
an elongated bumper core of a polyolefin-based resin-
containing foam having a density of 0.045-0.2 g/cm^3,
15 comprising at least two, vertically spaced apart U-shaped
sections each formed by a vertical front wall extending
lengthwise of said bumper core and at least two legs
extending longitudinally and also rearwardly from said
vertical front wall to define between adjacent two legs a
20 space which is open rearwardly; and an interconnecting
section connecting adjacent two legs of each of the two
adjacent U-shaped sections at a position spaced apart
rearwardly from at least one of said front walls of said
adjacent two U-shaped sections so that the U-shaped
25 sections are interconnected together into a unitary
structure.

The present invention also provides a bumper for
attachment to a front of a vehicle, comprising a bumper
fascia, the above bumper core having a front side attached
30 to said bumper fascia, and a reinforcement to which a rear
side of the bumper core is attached.

BRIEF DESCRIPTION OF THE DRAWINGS
Other objects, features and advantages of the
35 present invention will become apparent from the detailed

description of the preferred embodiments of the invention which follows, when considered in the light of the accompanying drawings in which:

FIG. 1 shows compression curves of a bumper core of the present invention (curve a) and known bumper cores (curves b and c);

FIG. 2(a) is a front elevational view schematically illustrating a compression test method;

FIG. 2(b) is a side view of FIG. 2(a);

FIG. 3(a) is a vertical elevational view diagrammatically illustrating one embodiment of a bumper core according to the present invention;

FIG. 3(b) is a side view of FIG. 3(a);

FIG. 4 is a lateral cross-sectional view diagrammatically illustrating one example of a bumper structure of the present invention;

FIG. 5 is an enlarged fragmentary view of a portion of the bumper core shown in FIG. 3(b);

FIG. 6(a) is a vertical elevational view diagrammatically illustrating another embodiment of a bumper core according to the present invention;

FIG. 6(b) is a side view of FIG. 6(a);

FIG. 6(c) is a perspective view of the bumper core of FIG. 6(a);

FIGS. 7(a) through 7(j) are side views similar to FIG. 6(b), showing various modifications of the bumper core of FIG. 6(b);

FIG. 8 is an enlarged fragmentary view of a portion of the bumper core shown in FIG. 6(b); and

FIGS. 9(a) through 9(h) are perspective views diagrammatically illustrating bumper core specimens prepared and tested in the examples and comparative examples.

DETAILED DESCRIPTION OF THE PREFERRED
EMBODIMENTS OF THE INVENTION

The elongated bumper core of the present invention is made of a polyolefin-based resin-containing foam and shows a compressive load of F_{20} at 20 % strain, a compressive load of F_{40} at 40 % strain and a compressive load of F_{60} at 60 % strain when compressed by a rigid pipe having an outer diameter of 70 mm at a compression speed of 500 mm/minute. It is important that the ratio F_{20}/F_{40} should be in the range of 0.6-1.3 and the ratio F_{60}/F_{40} should be in the range of 0.75-1.3.

When the ratios F_{20}/F_{40} and F_{60}/F_{40} fall within the above ranges, the bumper core typically shows a strain-stress curve "a" shown in FIG. 1. Because of the presence of such a "flat" portion in the strain-stress curve "a" between the 20 % strain and the 60 % strain, the compressive load initially greatly changes in the 0-20 % strain range. In the 20 % to 60 % strain range, however, the change in compressive load is small. Thus, the collision energy can be absorbed in the flat portion. Further, the compressive loads in the flat portion do not greatly exceed the compressive load F_{40} at the 40 % strain.

More specifically, when the ratio F_{20}/F_{40} is less than 0.6, an increase of the compressive load in the initial, low strain range is so small as shown by the curve "b" in FIG. 1 that the collision energy cannot be sufficiently absorbed. On the other hand, when the ratio F_{20}/F_{40} is greater than 1.3, a peak appears in a low strain region as shown by the curve "c" in FIG. 1. When the peak is high as shown in FIG. 1, the leg stress is so high that there is a great possibility that the leg is seriously damaged. When the peak is low, the collision energy cannot be sufficiently absorbed and the leg cannot be sufficiently protected. For reasons of sufficient protection of the leg and sufficient absorption of the

collision energy, the ratio F_{20}/F_{40} is preferably in the range of 0.75-1.3, more preferably in the range of 0.8-1.2, most preferably in the range of 0.85-1.1.

When the ratio F_{60}/F_{40} is less than 0.75, the compressive load decreases relatively rapidly at the strain of 40 % or more, resulting in a failure to absorb the collision shock sufficiently. Further, since the strain-stress curve will finally abruptly increase by the applied collision energy, the leg impact increases considerably to cause serious injury. When the ratio F_{60}/F_{40} exceeds 1.3, strain-stress curve increases so rapidly at the strain range of F_{40} to F_{60} that the leg cannot be sufficiently protected from collision impact. For reasons of sufficient protection of the leg and sufficient absorption of the collision energy, the ratio F_{60}/F_{40} is preferably in the range of 0.8-1.2, more preferably in the range of 0.85-1.15, still more preferably 0.98-1.15, most preferably 1.0-1.1.

It is preferred that the compressive load F_{40} at the 40 % strain be in the range of 1-6 kN, more preferably 2-5 kN, for reasons of sufficient absorption of the collision energy and sufficient protection of the leg from the collision impact. For the same reasons, the compressive load F_{20} at the 20 % strain is preferably in the range of 0.7-6 kN, more preferably 2-5 kN, while the compressive load F_{20} at the 60 % strain is preferably in the range of 1-6 kN, more preferably 2-6 kN.

As used herein, the compression curve is intended to refer to plots of the compressive load as a function of the strain obtained in a compression test in which the core is compressed by a rigid pipe having an outer diameter of 70 mm at a compression speed of 500 mm/minute. The compression test is carried out at 23°C under a relative humidity of 50 %. The pipe diameter of 70 mm is selected as an approximate diameter of an adult leg.

The compression test method will be described in detail below with reference to FIGS. 2(a) and 2(b) which are front and side views, respectively, schematically illustrating a specimen 1 of a core under the compression

5 test. The specimen 1 in the illustrated case is obtained by laterally cutting an elongated core 10 shown in FIGS. 3(a) and 3(b) into a length "d" of 17 cm. Thus, the specimen 1 has a length "d" along the lengthwise direction of the core 10 of 17 cm, a length "t" along the front-to-

10 rear direction of the core 10 and a length "h" along the vertical direction of the core 10, the length "h" being the same as or smaller than a vertical length of a front surface of a reinforcement (designated as 19 in FIG. 4 and described hereinafter) to which the core 10 is attached.

15 In sampling, each of the longitudinal end portions having a longitudinal length equal to 15 % of the total length of the core 10 is removed. Further, those regions of the core 10 which correspond to the locations of winkers and headlamps and which have special shapes are removed.

20 Additionally, upper and lower portions of the core 10 which protrude from the upper and lower edges of a reinforcement, if any, are removed. From the remaining core (essential part of the core), as large a number of specimens as possible are produced and each specimen is

25 subjected to the compression test.

In FIGS. 2(a) and 2(b), designated as 3 is a rigid supporting table having a flat surface to which a #40 sand paper 5 is bonded with its rough surface being upwardly facing surface. The specimen 1 is placed on the table 3

30 such that the rear side of the core is in contact with the rough surface of the sand paper 5. Then, the rigid pipe 2 having an outer diameter of 70 mm is placed on the specimen such that the axial direction of the pipe 2 is oriented normal to the lengthwise direction of the

35 specimen. A compression device 4 is operated to lower the

pipe 2 so that the specimen is compressed in the front-to-rear direction at a compression speed of 500 mm/minute. The compression is conducted, while recording the applied load and the height of the specimens, until each specimen

5   is compressed by 70 %, i.e. until the length "t" is reduced to 0.3t. From the thus obtained compression curve, a compressive load of F_{20} at 20 % strain, a compressive load of F_{40} at 40 % strain and a compressive load of F_{60} at 60 % strain are determined for each specimen. Then, an

10   average of the compressive loads of the specimens is calculated for each of F_{20}, F_{40} and F_{60}, from which F_{20}/F_{40} and F_{60}/F_{40} of the core are determined.

The elongated core of the present invention extends lengthwise, i.e. in the longitudinal direction, which is

15   in parallel with the lateral direction of a vehicle such as an automobile to which the bumper is attached to a front of the vehicle. The elongated core also extends in a front-to-rear direction of the core. The front-to-rear direction of the core is perpendicular to the lengthwise

20   direction thereof and is in parallel with the front-to-rear direction of the vehicle. The maximum length L of the core along the front-to-rear direction is generally 15 cm or less, preferably 3-15 cm, more preferably 4-12 cm. Too large a maximum length L of the core in excess of 15

25   cm is not advantageous, because the front-to-rear length of the vehicle undesirably increases.

The bumper core having the above-described F_{20}/F_{40} and F_{60}/F_{40} characteristics may be embodied in various forms. One preferred embodiment of an elongated bumper

30   core according to the present invention is illustrated in FIGS. 3(a) and 3(b). Generally designated as 10 is an elongated bumper core having a front section 13 extending lengthwise of the bumper core 10, and at least two, longitudinally extending, vertically spaced apart

35   protrusions 12 each extending rearwardly from the front

section 13. In the illustrated embodiment, the front
section 13 is a vertical wall extending lengthwise of the
bumper core 10 and also vertically, while the protrusions
12 are four, parallel plate-like legs extending rearwardly
5   from and perpendicularly to the vertical wall 13 and
extending also lengthwise of the bumper core 10 to define
a space 15 between each of the adjacent two legs 12.

The space 15 between adjacent two legs 12 and 12
constitutes weight reducing portions which define air
10 space or plenum and in which only air is present.
Recesses, holes and/or grooves, when formed in the front
walls 13 and/or legs 12 also constitute such weight
reducing portions. Because of the presence of the weight
reducing portion 15, when the bumper core 10 as shown in
15 FIGS. 3(a) and 3(b) is compressed in the front-to-rear
direction, the legs 12 first begin deflecting and buckling.
Further compression of the bumper core 10 causes breakage
as well as further buckling of the legs. Thus, the core
10 continues to deform until the weight reducing portions
20 (air space) are filled with the buckled or broken legs.
As long as the legs continue to buckle and break roughly,
the compressive load does not greatly increase.

Therefore, in the above-described compression curve
shown in FIG. 1, there appears a flat portion between the
25 20 % strain and the 60 % strain in which the compressive
load does not greatly change. The compressive load F_{40} at
40 % strain increases with an increase of the strength of
the legs 12. Thus, by controlling the density of core,
the bending strength of the legs and the volume of the
30 weight reducing portions, it is possible to control the
compressive load and strain of the flat portion of the
compression curve. When an automobile, to which a front
bumper bearing the bumper core of the present invention
having the above compression curve characteristics is
35 attached, collides with an object, the energy of collision

can be absorbed while reducing the collision impact on the object.

It is preferred that the volume, VV cm^3, of the weight reducing portion (air space) 15 and the true volume, VT cm^3, of the bumper core 10 satisfy the following condition:

$$0.2 \leq VT/(VT + VV) \leq 0.7$$

for reasons of satisfactory absorption of the energy of collision and reduced collision impact. For example, when the volume VV of the weight reducing portion 15 is excessively large, namely when the legs 12 are excessively thin or excessively long, the ratio VT/(VT + VV) becomes so small that there is a possibility that the legs are vigorously crushed into fragments at a time of collision and that the compressive load abruptly decreases at 40-60 % strain. There is also a possibility that the collision impact cannot be absorbed sufficiently and that the compressive load considerably increases before the strain of 70 % is reached. On the other hand, when the volume VV of the weight reducing portion 15 is excessively small, namely when the legs 12 are excessively thick or excessively short, the ratio VT/(VT + VV) becomes so large that there is a possibility that the compression curve is as shown in the curve "b" in FIG. 1 and that the collision energy cannot be absorbed sufficiently and that the collision impact cannot be sufficiently reduced. More preferably, the ratio VT/(VT + VV) is between 0.2 and 0.6. Still more preferably, the ratio VT/(VT + VV) is between 0.2 and 0.5. Most preferably, the ratio VT/(VT + VV) is between 0.25 and 0.45.

The true volume VT of the bumper core 10 may be determined by measuring the dimensions thereof or, alternatively, by an immersion method in which a specimen is immersed in water to measure a difference between the water levels before and after the immersion from which the

volume VT can be determined. The volume VV of the weight
reducing portion 15 may be determined by measuring the
dimensions thereof. In an alternative, the volume (VT +
VV) is first measured from the dimensions of the core 10.

5   By subtracting the volume VT as measured by the immersion
method from the measured volume (VT + VV), the volume VV
may be determined.

The volumes VT and VV of the core under
consideration are those of the essential part of the core.

10   Thus, upper and lower portions of the core 10 which
protrude from the upper and lower edges of a reinforcement,
if any, are removed from the consideration. Additionally,
those regions of the core 10 which correspond to the
locations of winkers and headlamps and which have special

15   shapes are not taken in account. Further, each of the
longitudinal end portions having a longitudinal length
equal to 15 % of the total length of the core 10 is not
taken in account. For example, as shown in FIG. 4, upper
and lower portions 10b of the core 10 which protrude from

20   the upper and lower edges of a reinforcement 19 and which
are non-essential parts of the core are removed for the
measurement of VT and VV. Only the essential part 10a as
surrounded by the two-dotted line 22 in FIG. 4 is measured
for VT and VV. The dotted lines 18 show upper and lower

25   planes which are coplanar with the upper and lower
surfaces of the reinforcement 19 and which represent
boundaries between the essential part 10a and non-
essential part 10b. FIG. 4 depicts an embodiment of a
front bumper having a bumper fascia 16, the reinforcement

30   19 attached to a body of a vehicle, and the bumper core 10
interposed between the fascia 16 and the reinforcement 19
and secured to the reinforcement 19. Incidentally, the
volume VV of the weight reducing portion is the volume of
the air space within an imaginary flexible package

35   (designated as 22) enclosing the outer periphery of the

essential part of the core 10.

It is preferred that at least one of the legs 12 of
the core have a ratio (H/T) of the length, H mm, in the
front to rear direction to the thickness, T mm, in the
vertical direction of 2 to 10, more preferably 3-8, most
preferably 3-6. When the ratio H/T is excessively small,
namely when the thickness T is excessively large or the
length H is excessively small, there is a possibility that
the compression curve is as shown in the curve "b" in FIG.
1 and that the collision energy cannot be absorbed
sufficiently and the collision impact cannot be
sufficiently reduced. On the other hand, when the ratio
H/T is excessively large, namely when the thickness T is
excessively small or the length H is excessively large,
there is a possibility that the legs are vigorously
crushed into fragments at a time of collision and that the
compressive load abruptly decreases at 40-60 % strain.
There is also a possibility that the collision impact
cannot be absorbed sufficiently and that the compressive
load considerably increases before the strain of 70 % is
reached. The length H is preferably 20-100 mm, more
preferably 25-70 mm.

As shown in FIG. 5 which is an enlarged partial view
of a portion surrounded by the one-dotted line in FIG.
3(b), the length H of the leg 12 is a length from the base
position 21 to a rear end of the leg 12. The thickness T
of the leg 12 is a value obtained by dividing the cross-
sectional area S (mm^2) by the length H (T = S/H). The
cross-sectional area S is an area of the portion indicated
by the double line hatching in FIG. 5. It is possible
that the H and/or T of the leg 12 vary along the
longitudinal length of the core, i.e. along the
longitudinal length of the leg 12. Further, it is
possible that the leg 12 has a portion in which the ratio
H/T does not fall within the above-described range. In

such a case, however, it is preferred that the ratio H/T of the leg 12 fall within the above-described range in at least 60 % of the longitudinal length thereof.

It is also preferred that the polyolefin-based resin-containing foam from which the legs 12 are formed have a bending load BF of 35-400 N, more preferably 35-200 N, most preferably 70-200 N, for reasons of obtaining a suitable compressive load ratio F_{20}/F_{40}, F_{60}/F_{40} and a compressive load F_{40}. The bending load BF of the polyolefin-based resin-containing foam is measured by 3-point bending test in accordance with the method and conditions described in the Japanese Industrial Standard JIS K 7221 (1984) in terms of the maximum bending load. Thus, the specimen has a length of 120 mm, a width of 25 mm and a height of 20 mm. The specimen may be sampled from the leg of the essential part of the core 10. The same polyolefin-based resin-containing foam as used in the leg may be used as a specimen, if available.

It is further preferred that at least one of the legs has a bending load BL of 5-150 N, more preferably 25-75 N, most preferably 30-70 N, for reasons of obtaining a suitable compressive load ratio F_{20}/F_{40}, F_{60}/F_{40} and a compressive load F_{40}. The bending load BL of the leg is measured by 3-point bending test in accordance with the method and conditions described in the Japanese Industrial Standard JIS K 7221 (1984) in terms of the maximum bending load. However, the specimen should have a length of 120 mm and a width and a thickness of the leg as such. In the case of the leg 12 shown in FIG. 5, for example, a specimen is obtained by cutting the core along the line 21 and along the front-to-rear direction of the core such that the specimen has a length of 120 mm, a width of H and a thickness of T. The lengthwise direction of the specimen sampled is in parallel with the lengthwise direction of the core. The specimen thus obtained is

subjected to the 3-point bending test as such, even when
it has one or more tapered surfaces.

5   It is desired that at least one of the legs 12 of
the core have the H/T ratio, the bending loads BF and BL
in the above ranges. It is more preferred that at least
four legs 12 of the core meet with the these criteria. It
is most preferred that each of the legs 12 of the core

10   meet with the these criteria.
       The front wall 13 may have any desired shape such as
flat, concave, convex or undulated form to coincide with a
rear surface of a bumper fascia 18. If desired, the front
wall 13 may be provided with one or more through holes,

15   recesses or bores to form a part of the weight reducing
portion of the core 10. The thickness and shape of the
legs 12 may be suitably determined with due consideration
of the compressive strength at an initial stage of
collision (at low strain region) and easiness in

20   preparation of the core such as moldability and mold
releasability. For example, in the legs shown in FIG. 5,
the thickness of leg 12 in the base position 21 may be
greater than that in the rear end of the leg.
       Another preferred embodiment of an elongated bumper

25   core according to the present invention is illustrated in
FIGS. 6(a) through 6(c). The elongated bumper core,
generally designated as 100, in the illustrated embodiment
has two vertically spaced apart U-shaped sections 11a and
11b each formed by a vertical front wall 13a extending

30   lengthwise of the bumper core and two legs 12a and 12b
extending longitudinally and also rearwardly from the
vertical front wall 13a to define between adjacent two
legs 12a and 12b a space 15b which is open rearwardly.
Designated as 15a is a space between the adjacent U-shaped

35   sections 11a and 11b.
       The bumper core 100 also has an interconnecting
section 14 connecting adjacent two legs 12b and 12a of

each of the two adjacent U-shaped sections 11a and 11b at
a position spaced apart rearwardly from at least one of
the front walls 13a of the U-shaped sections 11a and 11b
so that the U-shaped sections 11a and 11b are
5 interconnected together into a unitary structure.

Various modifications may be made to the bumper core
100 shown in FIGS. 6(a) to 6(c). For example, the number
of the U-shaped sections may be changed if desired. Thus,
the number of the U-shaped sections 11a and 11b is
10 preferably 2-5, more preferably 2-3, most preferably 2.
Further, as shown in FIGS. 7(a) through 7(j), the number
of the legs in each U-shaped section, the orientation of
the front walls, the orientation of the legs and position
and orientation of the interconnecting section may be
15 changed as desired. The various modifications shown will
be described in more detail below. In FIGS. 6(a) to 6(c)
and FIGS. 7(a) to 7(j), the same reference numerals
designate similar component parts.

In the embodiment shown in FIG. 7(a), the adjacent
20 two legs 12b and 12a of the U-shaped sections 11a and 11b
are shorter than the other legs. In the core of FIG. 7(b),
the two legs 12a and 12b of the upper U-shaped section 11a
are shorter than those of the lower U-shaped section 11b,
and the vertical front walls 13a of the U-shaped sections
25 11a and 11b are not coplanar. The core shown in FIG. 7(c)
differs from that of FIG. 7(b) in that the leg 12a of the
lower U-shaped section 11b is shorter than that of the leg
12b thereof and in that the interconnecting section 14
extends between the rear end of the leg 12a of the lower
30 U-shaped section 11b and an intermediate portion of the
leg 12b of the upper U-shaped section 11a. In the
embodiments shown in FIGS. 7(d) and 7(e), each of the U-
shaped sections 11a and 11b has an additional legs 23
extending longitudinally and also rearwardly from the
35 vertical front wall 13a to divide the space 15b into two

sub-spaces. The number of the additional legs 23 in each of the U-shaped sections is generally 0-6, preferably 0-2, more preferably 0-1.

5 The legs 12a and 12b in the foregoing embodiments extend in parallel with each other. If desired, the legs may extend at a suitable angle. One example of such a non-parallel legs arrangement is illustrated in FIG. 7(f), in which the legs 12a and 12b extend rearwardly outwardly. The legs 12a and 12b may also extend inwardly. However, 10 it is preferred that the legs 12a and 12b extend in parallel with each other.

The interconnecting section 14 in the foregoing embodiments extend in parallel with the front walls 13a. If desired, however, the interconnecting section may not 15 be in parallel with the front walls 13a as shown in FIG. 7(g). Two or more interconnecting sections 14 may be provided as shown in FIG. 7(h), if desired. The front wall 13a in the foregoing embodiments extend in the direction normal to the front-to-rear direction of the 20 core 100. If desired, however, the front wall 13a of one or more U-shaped sections may extend obliquely as shown in FIG. 7(i).

In the foregoing embodiments, the rear end of the top leg 12a of the upper U-shaped section 11a and the rear 25 end of the lower leg 12b of the lower U-shaped section 11b are located in the same rearmost plane which is normal to the front-to-rear direction of the core 100. If desired, as shown in FIG. 7(j), the rear end of the lower leg 12b of the lower U-shaped section 11b may not be located in 30 the rearmost plane in which the rear end of the top leg 12a of the upper U-shaped section 11a is located. It is, however, preferred that the rear ends of the legs 12a and 12b of the U-shaped sections 11a and 11b be located in the same rearmost plane as in the embodiments of FIGS. 7(b), 35 7(e), 7(f), 7(g), 7(h) and 7(i).

The space 15b defined between the legs 12a and 12b and the space 15a defined between the two U-shaped sections 11a and 11b (see FIGS. 6(a) to 6(c)) constitute

5 weight reducing portions which define air space or plenum and in which only air is present. Recesses, holes and/or grooves, when formed in the front walls 13a, legs 12a and 12b and/or interconnecting section 14, also constitute such weight reducing portions. Because of the presence of

10 the weight reducing portions 15b and 15a, in the above-described compression curve shown in FIG. 1, there appears a flat portion between the 20 % strain and the 60 % strain in which the compressive load does not greatly change. Thus, by controlling the density of core, the bending

15 strength of the legs and the volume of the weight reducing portions, it is possible to control the compressive load and strain of the flat portion of the compression curve.

In the embodiments shown in FIGS. 6(a) to 6(c) and FIGS. 7(a) to 7(j), the interconnecting section 14

20 connects adjacent two legs 12b and 12a of each of the two adjacent U-shaped sections 11a and 11b at a position spaced apart rearwardly from the front walls 13a. It is preferred that the interconnecting section 14 be located at a position spaced apart from the foremost plane a

25 distance equal to at least one thirds, more preferably at least a half, still more preferably at least three quarters of the distance between the foremost plane and the rearmost plane.

The term "rearmost plane" as used herein is intended

30 to refer to the plane which is normal to the front-to-rear direction of the core 100 and in which at least one of the rearmost ends of the legs 12a and 12b is located. The term "foremost plane" as used herein is intended to refer to the plane which is in parallel with the rearmost plane and in which at least one of the foremost ends of the

35 front walls 13a is located. The terms "distance between

the foremost plane and the rearmost plane" is thus the maximum length of the core 100 in the front-to-rear direction and is indicated by L in FIGS. 7(a), 7(b) and 7(g) to 7(j). Thus, the location of the interconnecting

5   section 14 is preferably such that the length ℓ between the foremost plane and the front face of the interconnecting section 14 (see FIGS. 7(a), 7(b) and 7(g) to 7(j)) is at least L/3 ($\ell \geq L/3$), more preferably at least L/2, still more preferably at least 3L/4. Most

10   preferably, the position of the interconnecting section 14 is such that the rear face thereof is located in the rearmost plane as shown in FIGS. 6(b), 7(b), 7(e) and 7(f).

As described above, when the bumper core 100 having the weight reducing portions (air space) 15b and 15a is

15   compressed in the front-to-rear direction, the legs 12a and 12b first begin deflecting and buckling, and the core 100 continues to deform until the weight reducing portions are filled with the buckled or broken legs. As long as the legs continue to buckle and break roughly, the

20   compressive load does not greatly increase. Therefore, as shown by the curve "a" in FIG. 1, the compression curve of the bumper core 100 shows a flat portion between 20 % strain and 60 % strain in which the compressive load does not greatly change. When the buckling and breakage of the

25   legs terminate very quickly within a short period of time, on the other hand, there may appear a collapse in the compression curve as shown by the curve a' on rare occasions. Such an undesirable collapse of the compression curve can be avoided by controlling the

30   position of the interconnecting section 14 as described above.

For example, by increasing the bending strength of the legs 12a and 12b, the compressive load at an initial small strain increases. In this case, however, the flat

35   portion in which the legs continue to buckle and break

tends to shift toward the small strain side (leftward in the compression curve shown in FIG. 1) so that the compressive load F_{60} at 60 % strain tends to decrease. The interconnecting section 14 when positioned as described above serves to shift the flat portion in the compression curve toward the large strain side (rightward in the compression curve shown in FIG. 1).

The interconnecting section 14 preferably extends vertically and longitudinally. In this case, the interconnecting section 14 longitudinally extends continuously or intermittently with one or more gaps being defined between adjacent two components constituting the interconnecting section 14. The longitudinal length of the interconnecting section 14 preferably equals to 60-100 % of the longitudinal length of the bumper core 100. When the interconnecting section 14 has a discontinuous structure, the longitudinal length thereof is a total length of components constituting the interconnecting section 14. It is desirable that the interconnecting section 14 extends throughout the longitudinal length of the core 100.

For reasons of easiness in fabrication, the interconnecting section 14 is preferably in the form of a plate having a vertical length ("n" in FIG. 7(e)) of preferably 10-100 mm, more preferably 20-60 mm, most preferably 20-40 mm, and a thickness ("m" in FIG. 7(e)) in the front-to-rear direction of preferably 4-30 mm, more preferably 5-20 mm, most preferably 5-15 mm. The interconnecting section 14 is not limited only to a plate-like form, however.

Incidentally, one or more interconnecting walls each similar to the above described interconnecting section 14 may be provided in the bumper core 10 described with reference to FIGS. 3(a) and 3(b) to interconnect adjacent two legs 12 at a position spaced apart rearwardly from the

front section 13. In this case, the front section 13 may
be provided with at least one aperture. Such a structure
may become similar to the embodiments shown in FIGS. 6(a)
to 6(c) and FIGS. 7(a) to 7(j), depending upon the
5   position, number and shape of the aperture, leg and
interconnecting section. For example, when the core 10
shown in FIG. 3(b) is provided with an interconnecting
section to connect the inside two legs 15 at the rear ends
thereof and an aperture is formed in the front section 13
10   at a position opposite the interconnecting section, then
the resulting structure is similar to the core 100 shown
in FIG. 6(b).

It is preferred that the volume, VV cm^3, of the
weight reducing portion (air space) 15b and 15a and the
15   true volume, VT cm^3, of the bumper core 100 satisfy the
following condition:

$$0.2 \leq VT/(VT + VV) \leq 0.7$$

for reasons of satisfactory absorption of the energy of
collision and reduced collision impact, likewise in the
20   embodiment shown in FIGS. 3(a) and 3(b). More preferably,
the ratio $VT/(VT + VV)$ is between 0.2 and 0.6. Still more
preferably, the ratio $VT/(VT + VV)$ is between 0.2 and 0.5.
Most preferably, the ratio $VT/(VT + VV)$ is between 0.25
and 0.45.

25   It is preferred that the leg or legs 12a and/or 12b
of the core have a ratio (H/T) of the length, H mm, in the
front to rear direction to the thickness, T mm, in the
vertical direction of 2 to 10, more preferably 3-8, most
preferably 3-6, likewise in the embodiment shown in FIGS.
30   3(a) and 3(b). The length H is preferably 20-100 mm, more
preferably 25-70 mm.

As shown in FIG. 8 which is an enlarged partial view
of a portion surrounded by the one-dotted line in FIG.
6(b), the length H of the leg 12a is a length from the
35   base position 21 to a rear end of the leg 12a. The

thickness T of the leg 12a is a value obtained by dividing
the cross-sectional area S (mm^2) by the length H (T = S/H).
The cross-sectional area S is an area of the portion
indicated by the double line hatching in FIG. 8. It is
possible that the H and/or T vary along the longitudinal
length of the core. In such a case, it is preferred that
the ratio H/T of each of the legs 12a and 12b fall within
the above-described range in at least 60 % of the
longitudinal length thereof. In the embodiment shown in
FIG. 8, the leg 12b has the same length H and thickness T
as those of the leg 12a.

It is also preferred that the polyolefin-based
resin-containing foam from which the legs 12a and 12b are
formed have a bending load BF of 35-400 N, more preferably
35-200 N, most preferably 70-200 N, likewise in the
embodiment shown in FIGS. 3(a) to 3(c).

It is further preferred that at least one of the
legs 12a and 12b have a bending load BL of 5-150 N, more
preferably 25-75 N, most preferably 30-70 N, for reasons
of obtaining a suitable compressive load ratio F_{20}/F_{40},
F_{60}/F_{40} and a compressive load F_{40}. The bending load BL of
the leg is measured by 3-point bending test in accordance
with the method and conditions described in the Japanese
Industrial Standard JIS K 7221 (1984) in terms of the
maximum bending load, as described above. However, the
specimen should have a length of 120 mm and a width and a
thickness of the leg as such. In the case of the leg 12b
as shown in FIG. 8, for example, a specimen is obtained by
cutting the core along the lines 21 and 25 and along the
front-to-rear direction of the core such that the specimen
has a length of 120 mm, a width of H and a thickness of T.
The lengthwise direction of the specimen sampled is in
parallel with the lengthwise direction of the core. The
specimen thus obtained is subjected to the 3-point bending
test as such, even when it has one or more tapered

surfaces.

It is desired that at least one of the legs of the
core have the H/T ratio, the bending loads BF and BL in
the above ranges. It is more preferred that at least four
5   legs of the core meet with the these criteria. It is most
preferred that each of the legs of the core meet with the
these criteria.

The front wall 13a of the core 100 preferably has
such a shape as to coincide with a rear surface of a
10   bumper fascia 18. However, the front wall 13a may have
any desired shape such as flat, concave, convex or
undulated form. If desired, the front wall 13a may be
provided with one or more through holes, recesses or bores
to form a part of the weight reducing portion of the core
15   100. The thickness and shape of the legs 12a and 12b may
be suitably determined with due consideration of the
compressive strength at an initial stage of collision (at
low strain region) and easiness in preparation of the core
such as moldability and mold releasability.

20   It is important that the bumper core be formed of a
polyolefin-based resin foam having a density D2 of 0.045-
0.2 g/cm^3. Too low a density D2 below 0.045 g/cm^3 is
undesirable because the energy absorption is insufficient.
A density D2 in excess of 0.2 g/cm^3 is also undesirable
25   because the compressive load F_{40} at 40 % strain is too
high to reduce leg impact on the pedestrian. The density
D2 is preferably 0.06-0.19 g/cm^3, more preferably 0.075-
0.19 g/cm^3, most preferably 0.09-0.15 g/cm^3. The density
D2 of the bumper core is calculated by dividing the volume
30   thereof by the weight thereof. The volume is measured by
an immersion method in which a specimen is immersed in
water to measure a difference between the water levels
before and after the immersion, from which the volume can
be determined.

35   The polyolefin-based resin for use in the bumper

core may be, for example, a propylene-based resin such as
a propylene homopolymer, a propylene-butene random
copolymer, a propylene-butene block copolymer, an
propylene-ethylene block copolymer, an propylene-ethylene
5   random copolymer or an propylene-ethylene-butene random
terpolymer; an ethylene-based resin such as a low density
polyethylene, a medium density polyethylene, a high
density polyethylene, a linear low density polyethylene, a
linear very low density polyethylene, an ethylene-vinyl
10   acetate copolymer, an ethylene-methyl methacrylate
copolymer, an ionomer resin obtainable by inter-molecular
crosslinking of an ethylene-methacrylic acid copolymer
with a metal ion or an ethylene-acrylic acid-maleic
anhydride terpolymer; polybutene-1 and polypentene. The
15   polyolefin-based resin preferably contains at lest 30 % by
weight, more preferably at least 50 % by weight, most
preferably at least 80 % by weight, of olefin components
in the polymer chains thereof for reasons of good
resilience, workability and recycling efficiency of the
20   bumper core. The polyolefin-based resin is preferably a
propylene-based resin.

It is also preferred that the polyolefin-based resin
have a tensile modulus of at least 1,200 MPa, more
preferably at least 1,350 MPa, most preferably at least
25   1,500 MPa, because a light weight and high rigidity bumper
core having excellent energy absorption characteristics
can be obtained. The upper limit of the tensile modulus
is generally about 3,000 MPa. Most propylene homopolymers
have such a high tensile modulus. Propylene copolymers
30   having a high propylene content may also have such a high
tensile modulus. The term "tensile modulus" as used
herein is as measured in accordance with the Japanese
Industrial Standard JIS K 7161(1994) using a specimen of a
1A shape (molded directly by injection molding) specified
35   in JIS K 7162(1994) at a testing rate of 1 mm/minute.

If desired, the polyolefin-based resin may be used in conjunction with one or more other polymers as long as the object of the present invention is accomplished. Such additional polymers may be, for example, a polystyrene

5   resin, a styrene elastomer, an olefin elastomer or an olefin rubber.

The bumper core of the polyolefin-based resin-containing foam is preferably prepared as a unitary body by molding expanded beads of a base resin containing the

10   polypropylene-based resin in a mold. The expanded beads may be prepared by any suitable known method.

The following examples will further illustrate the present invention.

15   Example 1

Expanded beads (apparent density D1: 0.14 g/cm^3) of a propylene homopolymer resin having a tensile modulus of 1,440 MPa were filled in a mold and heated with steam to obtain a foamed molding in the form of a bumper core

20   having a maximum length L in the front-to-rear direction of 38 mm. The core was composed of a front wall, and two, parallel plate-like legs extended rearwardly from the front wall and also lengthwise of the core. From the essential portion of the thus obtained core were cut out

25   specimens as shown in FIG. 9(a) each having a length "d" of 170 mm in the lengthwise direction of the core, the length "t" of 38 mm in the front-to-rear direction of the core and a vertical length "h" of 100 mm along the vertical direction of the core. Each specimen had two

30   legs with a length H in the front-to-rear direction of 32 mm and a thickness T in the vertical direction of 8 mm. The specimens were measured for a compressive load F_{20} at 20 % strain, a compressive load F_{40} at 40 % strain, a compressive load F_{60} at 60 % strain, a true volume VT and

35   a volume VV of the weight reducing portion, from which

F_{20}/F_{40}, F_{60}/F_{40} and VT/(VT + VV) were calculated. Also measured was the density D2 of the foamed molding, bending load BL of the leg and the bending load BF of the foam from which the leg was formed. The results are summarized in Tables 1 and 2.

The apparent density (D1) of the expanded beads is obtained by dividing the volume (V1) thereof by the weight (W1) thereof (D1 = W1/V1). The volume (V1) is measured by an immersion method in which more than 500 expanded beads (weight W1), which have been allowed to stand at 23°C for 48 hours in the atmosphere under a relative humidity of 50 %, are immersed in water contained in a graduation cylinder. From the increment of the volume, the volume (V1) can be determined.

Example 2

Using the same expanded beads as used in Example 1, a bumper core was molded in the same manner as in Example 1 having a maximum length L in the front-to-rear direction of 38 mm. The core was composed of a front wall, and four, parallel, equally spaced apart plate-like legs extending rearwardly from the front wall and also lengthwise of the core. From the essential portion of the thus obtained core were cut out specimens as shown in FIG. 9(b) each having a length "d" of 170 mm in the lengthwise direction of the core, the length "t" of 38 mm in the front-to-rear direction of the core and a vertical length "h" of 100 mm along the vertical direction of the core. Each specimen had four legs with a length H in the front-to-rear direction of 32 mm and a thickness T in the vertical direction of 8 mm. The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 of the core and bending loads BL and BF of the leg are shown in Tables 1 and 2.

Example 3

Using the same expanded beads as used in Example 1,
a bumper core was molded in the same manner as in Example
1 having a maximum length L in the front-to-rear direction
5 of 38 mm. The core was composed of a front wall, and five,
parallel, equally spaced apart plate-like legs extending
rearwardly from the front wall and also lengthwise of the
core. From the essential portion of the thus obtained
core were cut out specimens as shown in FIG. 9(c) each
10 having a length "d" of 170 mm in the lengthwise direction
of the core, the length "t" of 38 mm in the front-to-rear
direction of the core and a vertical length "h" of 100 mm
along the vertical direction of the core. Each specimen
had five legs with a length H in the front-to-rear
15 direction of 32 mm and a thickness T in the vertical
direction of 8 mm. The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40},
VT/(VT + VV) and D2 of the core and bending loads BL and
BF of the leg are shown in Tables 1 and 2.

20 Example 4

Example 2 was repeated in the same manner as
described except that expanded beads (apparent density D1:
0.076 g/cm^3) of a propylene-ethylene random copolymer
resin having a tensile modulus of 1,120 MPa were used for
25 the preparation of a molded bumper core having a maximum
length L in the front-to-rear direction of 38 mm. The
core was composed of a front wall, and four, parallel,
equally spaced apart plate-like legs extending rearwardly
from the front wall and also lengthwise of the core. From
30 the essential portion of the thus obtained core were cut
out specimens as shown in FIG. 9(b) each having a length
"d" of 170 mm in the lengthwise direction of the core, the
length "t" of 38 mm in the front-to-rear direction of the
core and a vertical length "h" of 100 mm along the
35 vertical direction of the core. Each specimen had four

legs with a length H in the front-to-rear direction of 32 mm and a thickness T in the vertical direction of 8 mm. The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 of the core and bending loads BL and BF of the leg are shown in Tables 1 and 2.

Example 5

Example 2 was repeated in the same manner as described except that the thickness T was increased to 12 mm. The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 of the core and bending loads BL and BF of the leg are shown in Tables 1 and 2.

Example 6

Expanded beads (apparent density D1: 0.16 g/cm^3) of a propylene-ethylene random copolymer resin having a tensile modulus of 1,120 MPa were filled in a mold and heated with steam to obtain a foamed molding in the form of a bumper core having a maximum length L in the front-to-rear direction of 38 mm. The core was composed of a front wall, and four, parallel, equally spaced apart plate-like legs extending rearwardly from the front wall and also lengthwise of the core. From the essential portion of the thus obtained core were cut out specimens as shown in FIG. 9(b) each having a length "d" of 170 mm in the lengthwise direction of the core, the length "t" of 38 mm in the front-to-rear direction of the core and a vertical length "h" of 100 mm along the vertical direction of the core. Each specimen had four legs with a length H in the front-to-rear direction of 32 mm and a thickness T in the vertical direction of 9 mm. The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 of the core and bending loads BL and BF of the leg are shown in Tables 1 and 2.

Example 7

Expanded beads (apparent density D1: 0.16 g/cm^3) of a propylene homopolymer resin having a tensile modulus of 1,440 MPa were filled in a mold and heated with steam to

5   obtain a foamed molding in the form of a bumper core. The core had two vertically spaced apart U-shaped sections each formed by a vertical front wall extending lengthwise of the bumper core and two legs extending longitudinally and also rearwardly from the vertical front wall to define

10   between adjacent two legs a space which is open rearwardly. The core had an interconnecting section connecting adjacent two legs of the adjacent two U-shaped sections at rear ends of the legs so that the U-shaped sections are interconnected together into a unitary structure. From

15   the essential portion of the thus obtained core were cut out specimens as shown in FIG. 9(d) each having a length "d" of 170 mm in the lengthwise direction of the core, the length "t" of 38 mm in the front-to-rear direction of the core and a vertical length "h" of 100 mm along the

20   vertical direction of the core. Each specimen had four legs with a length H in the front-to-rear direction of 32 mm and a thickness T in the vertical direction of 9 mm. The interconnecting section was in the form of a rectangular plate having a vertical length "n" of 20 mm

25   and a thickness "m" in the front-to-rear direction of 6 mm. The specimens were measured for a compressive load F_{20} at 20 % strain, a compressive load F_{40} at 40 % strain, a compressive load F_{60} at 60 % strain, a true volume VT and a volume VV of the weight reducing portion, from which

30   F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) were calculated. Also measured were the density D2 of the core, the bending load BL of the leg and the bending load BF of the foam. The results are summarized in Tables 1 and 2.

35

Example 8

Example 7 was repeated in the same manner as described except that the interconnecting section was located at a position spaced apart from the foremost plane of the core a distance equal to three quarters of the distance between the foremost plane and the rearmost plane of the core (namely, the length l between the foremost plane and the front face of the interconnecting section in FIG. 9(e) was 38×3/4 (= 28.5) mm). The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 of the core and bending loads BL and BF of the leg are shown in Tables 1 and 2.

Comparative Example 1

Expanded beads (apparent density D1: 0.13 g/cm^3) of a propylene homopolymer resin having a tensile modulus of 1,440 MPa were filled in a mold and heated with steam to obtain a foamed molding in the form of a rectangular parallelepiped as shown in FIG. 9(f) having a thickness "t" of 38 mm, a length "d" of 170 mm and a width "h" of 100 mm. The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 and bending load BF of the foam are shown in Tables 1 and 2. The compression test was carried out in a manner as shown in FIGS. 2(a) and 2(b). Thus, the foam was compressed in the thickness direction with the axis of a pipe (jig) 2 being oriented in the direction perpendicular to the lengthwise of the foam.

Comparative Example 2

Comparative Example 1 was repeated in the same manner as described except that expanded beads (apparent density D1: 0.059 g/cm^3) of a propylene homopolymer resin having a tensile modulus of 1,440 MPa were molded to form a foamed molding in the form of a rectangular parallelepiped as shown in FIG. 9(f) having a thickness

"t" of 38 mm, a length "d" of 170 mm and a width "h" of 100 mm. The foamed molding had a density of 0.039 g/cm^3. The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 and bending load BF of the foam are shown in Tables 1 and 2.

Comparative Example 3

Example 1 was repeated in the same manner as described except that the thickness T of the leg in the vertical direction was increased to 20 mm. The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 of the core and bending loads BL and BF of the leg are shown in Tables 1 and 2.

Comparative Example 4

Example 2 was repeated in the same manner as described except that the maximum length L was increased to 100 mm and that the length H of the leg in the front-to-rear direction was increased to 94 mm. The specimen of the core had a shape as shown in FIG. 9(g). The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 of the core and bending loads BL and BF of the leg are shown in Tables 1 and 2.

Comparative Example 5

Example 2 was repeated in the same manner as described except that the expanded beads had an apparent density D1: 0.059 g/cm^3 and that the propylene-ethylene random copolymer resin had a tensile modulus of 1,120 MPa. The F_{20}, F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 of the core and bending loads BL and BF of the leg are shown in Tables 1 and 2.

Comparative Example 6

Example 1 was repeated in the same manner as described except that the maximum length L was increased

to 44 mm, that the length H of the leg in the front-to-rear direction was increased to 38 mm and that apertures were formed in the front wall. Thus, the core was composed of a front wall, and two parallel plate-like legs

5 extended rearwardly from the front wall and also lengthwise of the core. The front wall was then cut to form apertures arranged along the lengthwise of the core and spaced apart from each other a distance of 40 mm, with each aperture having a length in the lengthwise direction

10 of the core of 150 mm and a width in the vertical direction of the core of 84 mm. From the essential portion of the thus obtained core were cut out specimens as shown in FIG. 9(h) each having a length "d" of 170 mm in the lengthwise direction of the core, the length "t" of

15 44 mm in the front-to-rear direction of the core and a vertical length "h" of 100 mm along the vertical direction of the core. Each specimen had two plate-like legs with a length H in the front-to-rear direction of 38 mm and a thickness T in the vertical direction of 8 mm. The F_{20},

20 F_{40}, F_{60}, F_{20}/F_{40}, F_{60}/F_{40}, VT/(VT + VV) and D2 of the core and bending loads BL and BF of the leg are shown in Tables 1 and 2.

Table 1

Example	Apparent Density D1 of Beads (g/cm³)	Density D2 of Core (g/cm³)	VT/ (VT+ VV)	Leg				Connecting Section	
				Number	Length H (mm)	Thick- ness T (mm)	H/T	Thick- ness m (mm)	Vertical length n (mm)
1	0.14	0.099	0.29	2	32	8	4	-	-
2	0.14	0.099	0.43	4	32	8	4	-	-
3	0.14	0.099	0.50	5	32	8	4	-	-
4	0.076	0.051	0.43	4	32	8	4	-	-
5	0.14	0.099	0.56	4	32	12	2.7	-	-
6	0.16	0.113	0.46	4	32	9	3.6	-	-
7	0.16	0.113	0.46	4	32	9	3.6	6	20
8	0.16	0.113	0.46	4	32	9	3.6	6	20
Comp. 1	0.13	0.090	1	-	-	-	-	-	-
Comp. 2	0.059	0.039	1	-	-	-	-	-	-
Comp. 3	0.14	0.099	0.50	2	32	20	1.6	-	-
Comp. 4	0.14	0.099	0.36	4	94	8	11.8	-	-
Comp. 5	0.059	0.039	0.43	4	32	8	4	-	-
Comp. 6	0.14	0.099	0.17	2	38	8	4.8	-	-

Table 2

Example	Foam BF (N)	Core BL (N)	F_{20} (kN)	F_{40} (kN)	F_{60} (kN)	F_{20}/F_{40}	F_{60}/F_{40}
1	120	32	1.02	1.16	1.03	0.88	0.89
2	120	32	2.26	2.74	2.96	0.82	1.08
3	120	32	2.68	3.24	3.72	0.83	1.15
4	45	6	0.50	0.65	0.80	0.77	1.23
5	120	63	3.23	4.64	5.90	0.70	1.27
6	138	48	3.26	4.01	3.69	0.81	0.92
7	138	48	2.96	3.86	4.07	0.77	1.05
8	138	48	3.00	4.08	4.29	0.74	1.05
Comp. 1	106	–	5.13	7.91	10.66	0.65	1.35
Comp. 2	40	–	1.46	2.24	2.96	0.65	1.32
Comp. 3	120	153	2.78	4.11	5.54	0.68	1.35
Comp. 4	120	54	0.73	0.01	0.14	73	14
Comp. 5	32	4	0.46	0.58	0.70	0.79	1.13
Comp. 6	120	38	0.97	0.97	0.01	1.00	0.01

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all the changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

The teachings of Japanese Patent Applications No. 2002-249532, filed August 28, 2002 and No. 2002-332583, filed November 15, 2002, inclusive of the specifications, claims and drawings, are hereby incorporated by reference herein.